Source: Editor of UTRA/FDD physical layer description

SMG2 UMTS Physical Layer Expert Group

UTRA Physical Layer Description FDD parts (v0.4, 1998-06-25)

This document describes the UTRA/FDD physical layer. This version v0.4 is based on v0.3.1, and is updated with the agreed changes at the Turin UMTS-L1 meeting, June 15-17.

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1 UTRA physical layer – general description

1.1 Introduction

1.2 Definitions and abbreviations

ARQ	Automatic Repeat Request
BCCH	Broadcast Control Channel
BER	Bit Error Rate
BLER	Block Error Rate
BS	Base Station
CCPCH	Common Control Physical Channel
DCH	Dedicated Channel
DL	Downlink (Forward link)
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DS-CDMA	Direct-Sequence Code Division Multiple Access
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FER	Frame Error Rate
Mcps	Mega Chip Per Second
MS	Mobile Station
ODMA	Opportunity Driven Multiple Access
OVSF	Orthogonal Variable Spreading Factor (codes)
PCH	Paging Channel
PG	Processing Gain
PRACH	Physical Random Access Channel
PUF	Power Up Function
RACH	Random Access Channel
RX	Receive
SCH	Synchronisation Channel
SF	Spreading Factor
SIR	Signal-to-Interference Ratio
TDD	Time Division Duplex
TFI	Transport-Format Indicator
TPC	Transmit Power Control
TX	Transmit
UL	Uplink (Reverse link)
VA	Voice Activity

1.3 Normative references

1.4 General description

1.4.1 FDD

1.4.2 TDD

2 Transport channels and physical channels (FDD)

2.1 General

2.2 Transport channels

Transport channels are the services offered by Layer 1 to the higher layers.

2.2.1 Dedicated transport channels

There exists only one type of dedicated transport channel, the Dedicated Channel (DCH).

2.2.1.1 DCH - Dedicated Channel

The Dedicated Channel (DCH) is a downlink or uplink transport channel that is used to carry user or control information between the network and a mobile station. The DCH thus corresponds to the three channels Dedicated Traffic Channel (DTCH), Stand-Alone Dedicated Control Channel (SDCCH), and Associated Control Channel (ACCH) defined within ITU-R M.1035. The DCH is transmitted over the entire cell or over only a part of the cell using lobe-forming antennas.

2.2.2 Common transport channels

There are four types of common transport channels: BCCH, FACH, PCH, and RACH.

2.2.2.1 BCCH - Broadcast Control Channel

The Broadcast Control Channel (BCCH) is a downlink transport channel that is used to broadcast system- and cell-specific information. The BCCH is always transmitted over the entire cell.

2.2.2.2 FACH - Forward Access Channel

The Forward Access Channel (FACH) is a downlink transport channel that is used to carry control information to a mobile station when the system knows the location cell of the mobile station. The FACH may also carry short user packets. The FACH is transmitted over the entire cell or over only a part of the cell using lobe-forming antennas.

2.2.2.3 PCH - Paging Channel

The Paging Channel (PCH) is a downlink transport channel that is used to carry control information to a mobile station when the system does not know the location cell of the mobile station. The PCH is always transmitted over the entire cell.

2.2.2.4 RACH - Random Access Channel

The Random Access Channel (RACH) is an uplink transport channel that is used to carry control information from a mobile station. The RACH may also carry short user packets. The RACH is always received from the entire cell.

2.3 Physical channels

2.3.1 The physical resource

The basic physical resource is the code/frequency plane. In addition, on the uplink, different information streams may be transmitted on the I and Q branch. Consequently, a physical channel corresponds to a specific carrier frequency, code, and, on the uplink, relative phase (0 or $\pi/2$).

2.3.2 Uplink physical channels

2.3.2.1 Dedicated uplink physical channels

There are two types of uplink dedicated physical channels, the uplink Dedicated Physical Data Channel (uplink DPDCH) and the uplink Dedicated Physical Control Channel (uplink DPCCH).

The uplink DPDCH is used to carry dedicated data generated at Layer 2 and above, i.e. the dedicated transport channel (DCH). There may be zero, one, or several uplink DPDCHs on each Layer 1 connection.

The uplink DPCCH is used to carry control information generated at Layer 1. The Layer 1 control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, and an optional transport-format indicator (TFI). The transport-format indicator informs the receiver about the instantaneous parameters of the different transport channels multiplexed on the uplink DPDCH, see further Section 3, and corresponds to the data transmitted in the same frame. There is one and only one uplink DPCCH on each Layer 1 connection.

Figure 1 shows the frame structure of the uplink dedicated physical channel. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. A super frame corresponds to 72 consecutive frames, i.e. the super-frame length is 720 ms.

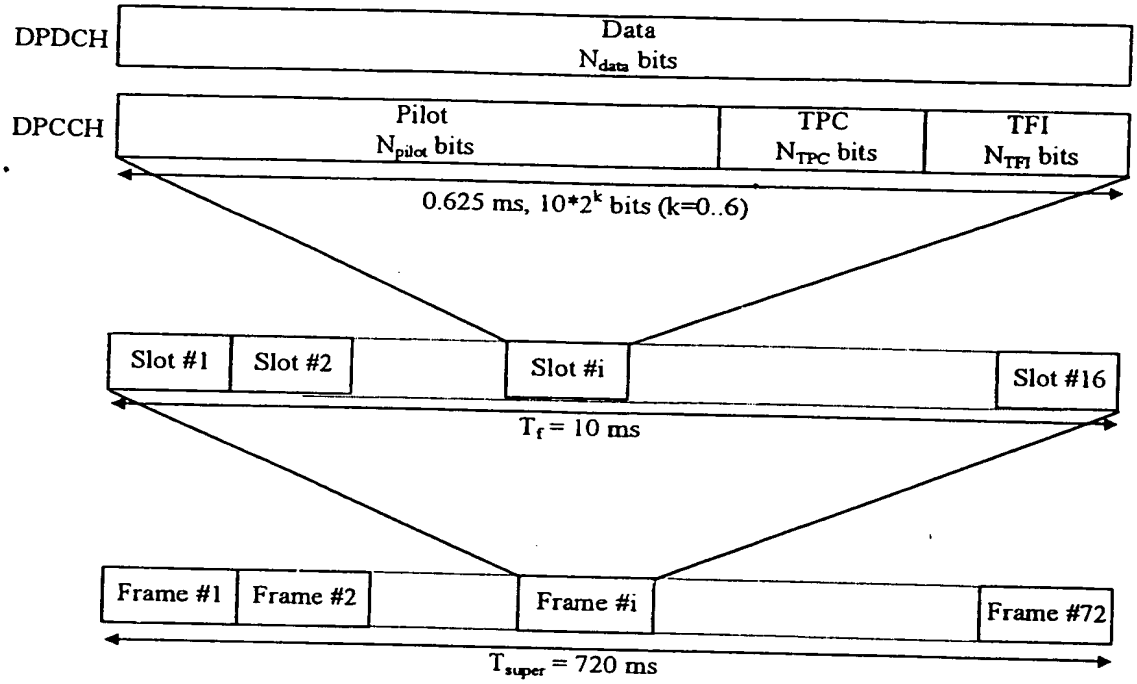


Figure 1. Frame structure for uplink DPDCH/DPCCH.

The parameter k in Figure 1 determines the number of bits per uplink DPDCH/DPCCH slot. It is related to the spreading factor SF of the physical channel as $SF = 256/2^k$. The spreading factor may thus range from 256 down to 4. Note that an uplink DPDCH and uplink DPCCH on the same Layer 1 connection generally are of different rates, i.e. have different spreading factors and different values of k.

The exact number of bits of the different uplink DPCCH fields in Figure 1 (N_{pilot}, N_{TPC}, and N_{TFI}) is yet to be determined.

Multi-code operation is possible for the uplink dedicated physical channels. When multi-code transmission is used, several parallel DPDCH are transmitted using different channelization codes, see Section 4.2.2.1. However, there is only one DPCCH per connection.

2.3.2.2 Common uplink physical channels

2.3.2.2.1 Physical Random Access Channel

The Physical Random Access Channel (PRACH) is used to carry the RACH. It is based on a Slotted ALOHA approach, i.e. a mobile station can start the transmission of the PRACH at a number of well-defined time-offsets, relative to the frame boundary of the received BCCH of the current cell. The different time offsets are denoted *access slots* and are spaced 1.25 ms apart as illustrated in Figure 2. Information on what access slots are available in the current cell is broadcast on the BCCH.

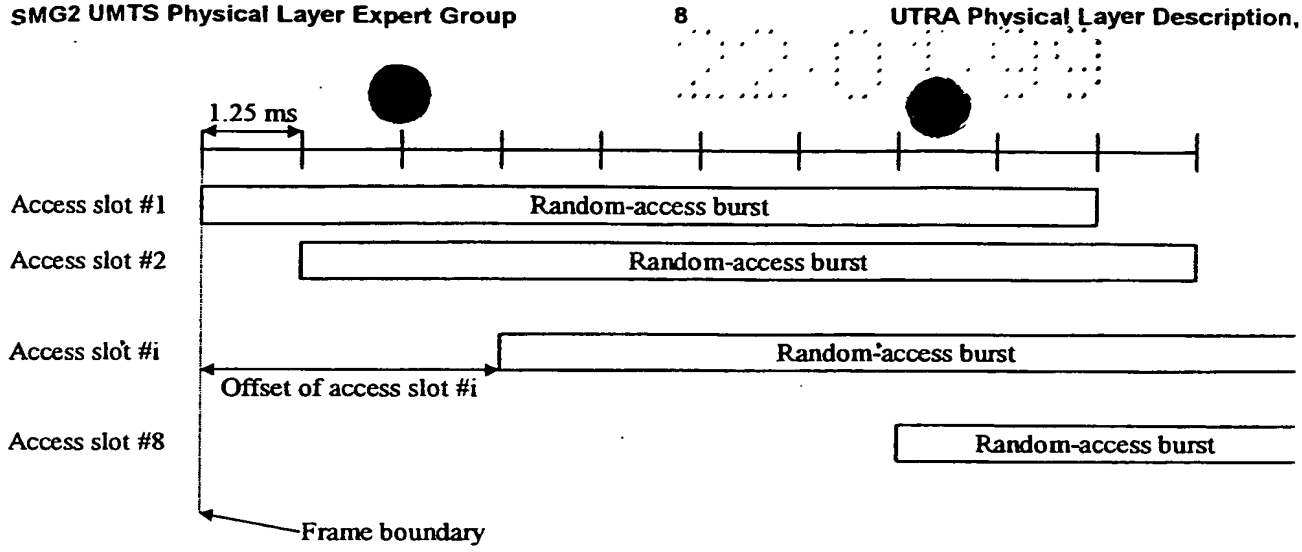


Figure 2. Access slots.

The structure of the random access burst of Figure 2, is shown in Figure 3. The random access burst consists of two parts, a *preamble* part of length 1 ms and a *message* part of length 10 ms. Between the preamble part and the message part there is an idle time period of length 0.25 ms (preliminary value). The idle time period allows for detection of the preamble part and subsequent on-line processing of the message part.

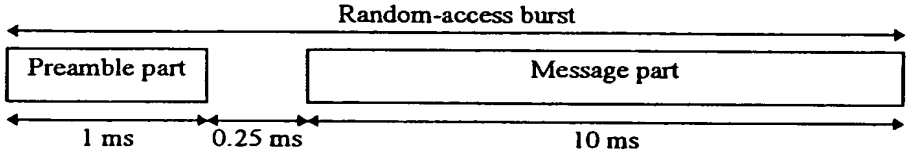


Figure 3. Structure of the Random Access burst.

Preamble part

The preamble part of the random-access burst consists of a *signature* of length 16 complex symbols (±1±j). Each preamble symbol is spread with a 256 chip real Orthogonal Gold code. There are a total of 16 different signatures, based on the Orthogonal Gold code set of length 16 (see Section 4.2.2.3.2 for more details).

Message part

The message part of the random-access burst has the same structure as the uplink dedicated physical channel. It consists of a data part, corresponding to the uplink DPDCH, and a Layer 1 control part, corresponding to the uplink DPCCH, see Figure 4. The data and control parts are transmitted in parallel. The data part carries the random access request or user packet. The spreading factor of the data part is limited to SF∈{256, 128, 64, 32} corresponding to channel bit rates of 16, 32, 64, and 128 kbps respectively. The control part carries pilot bits and rate information, using a spreading factor of 256. The rate information indicates which channelization code (or rather the spreading factor of the channelization code) is used on the data part, see further Section 4.2.2.3.

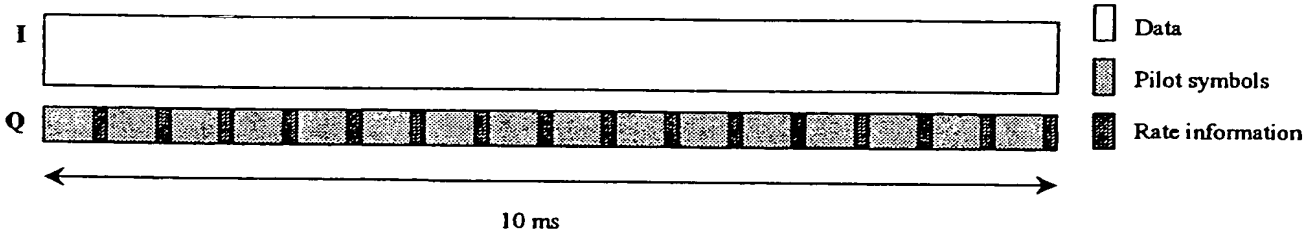


Figure 4. The message part of the random access burst.

Figure 5 shows the structure of the data part of the Random-Access burst. It consists of the following fields (the values in brackets are preliminary values):

- Mobile station identification (MS ID) [16 bits]. The MS ID is chosen at random by the mobile station at the time of each Random-Access attempt.

- Required Service [3 bits]. This field informs the base station what type of service is required (short packet transmission, dedicated-channel set-up, etc.)
- An optional user packet
- A CRC to detect errors in the data part of the Random-Access burst [8 bits].

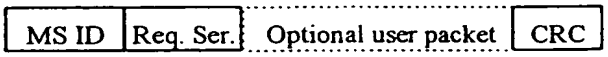


Figure 5. Structure of Random-Access burst data part.

< Editor's note: This should be elaborated and maybe moved to another expert group. >

2.3.3 Downlink physical channels

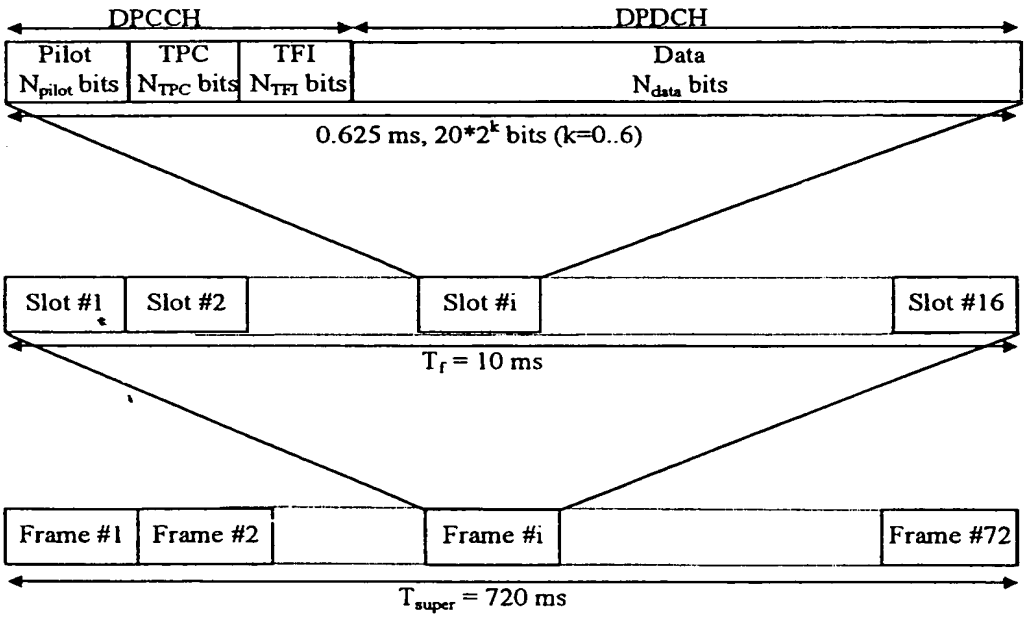
2.3.3.1 Dedicated physical channels

There is only one type of downlink dedicated physical channel, the Downlink Dedicated Physical Channel (downlink DPCH).

Within one downlink DPCH, dedicated data generated at Layer 2 and above, i.e. the dedicated transport channel (DCH), is transmitted in time-multiplex with control information generated at Layer 1 (known pilot bits, TPC commands, and an optional TFI). The downlink DPCH can thus be seen as a time multiplex of a downlink DPDCH and a downlink DPCCH, compare Section 2.3.2.1.

Figure 6 shows the frame structure of the downlink DPCH. Each frame of length 10 ms is split into 16 slots, each of length T_{slot} = 0.625 ms, corresponding to one power-control period. A super frame corresponds to 72 consecutive frames, i.e. the super-frame length is 720 ms.

Figure 6. Frame structure for downlink DPCH.



The parameter k in Figure 6 determines the total number of bits per downlink DPCH slot. It is related to the spreading factor SF of the physical channel as $SF = 256/2^k$. The spreading factor may thus range from 256 down to 4.

The exact number of bits of the different downlink DPCH fields in Figure 6 (N_{pilot}, N_{TPC}, N_{TFI}, and N_{data}) is yet to be determined.

Note that connection-dedicated pilot bits are transmitted also for the downlink in order to support the use of downlink adaptive antennas.

When the total bit rate to be transmitted on one downlink connection exceeds the maximum bit rate for a downlink physical channel, multicode transmission is employed, i.e. several parallel downlink DPCHs are transmitted for one connection using the same spreading factor. In this case, the Layer 1 control information is put on only the first downlink DPCH. The additional downlink DPCHs belonging to the connection do not transmit any data during the corresponding time period, see Figure 7.

Multiple codes may also transmitted in order to transmit different transport channels on different codes (code multiplex). In that case, the different parallel codes may have different spreading factors and the Layer 1 control information is transmitted on each code independently.

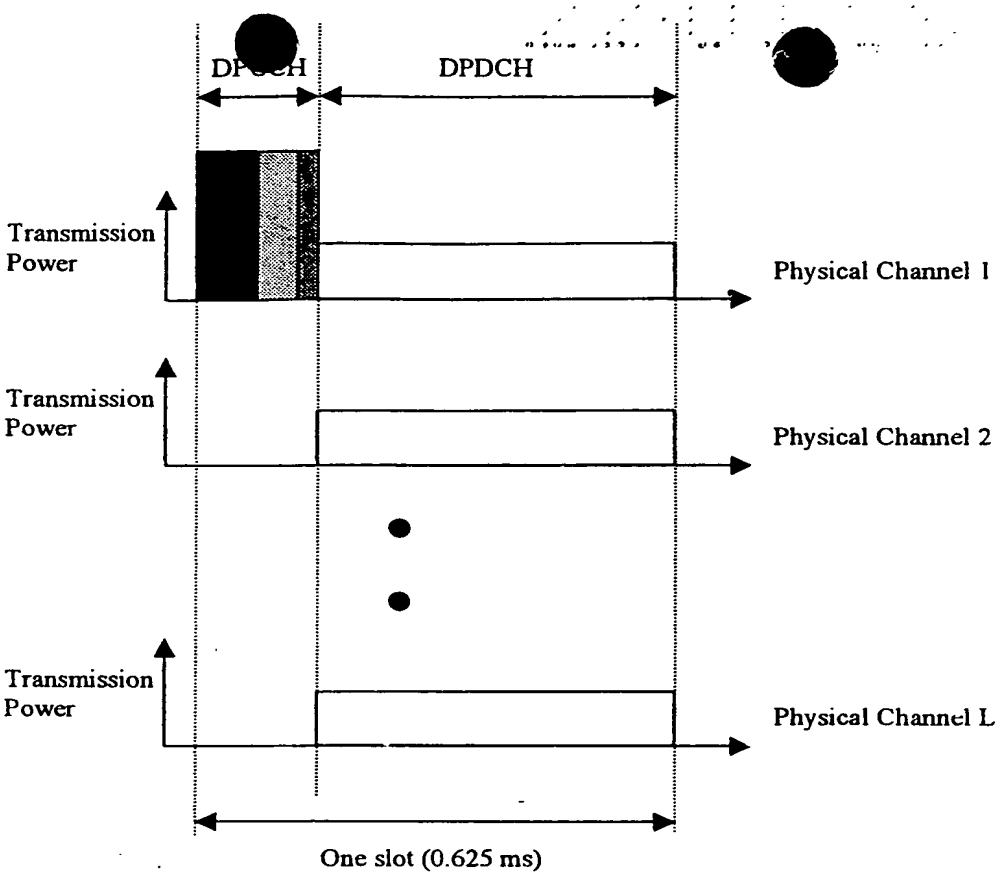


Figure 7. Downlink slot format in case of multi-code transmission.

2.3.3.2 Common physical channels

2.3.3.2.1 Primary Common Control Physical Channel (CCPCH)

The Primary CCPCH is a fixed rate (32 kbps, SF=256) downlink physical channels used to carry the BCCH. Figure 8 shows the frame structure of the Primary CCPCH. The frame structure differs from the downlink DPCH in that no TPC commands or TFI is transmitted. The only Layer 1 control information is the common pilot bits needed for coherent detection.

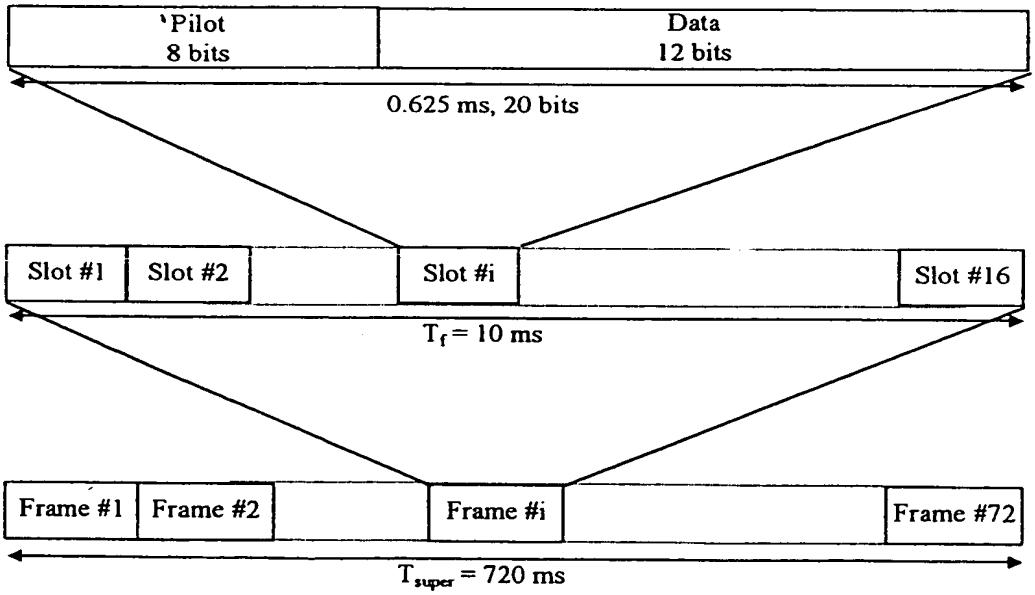


Figure 8. Frame structure for Primary Common Control Physical Channel.

2.3.3.2.2 Secondary Common Control Physical Channel

The secondary CCPCH is used to carry the FACH and PCH. It is of constant rate. However, in contrast to the Primary CCPCH, the rate may be different for different secondary CCPCH within one cell and between cells, in order to be able to allocate different amount of FACH and PCH capacity to a cell. The rate and spreading factor of each secondary CCPCH is broadcast on the BCCH. The set of possible rates is the same as for the downlink DPCH, see Section 2.3.3.1.

The frame structure of the Secondary CCPCH is shown in Figure 9.

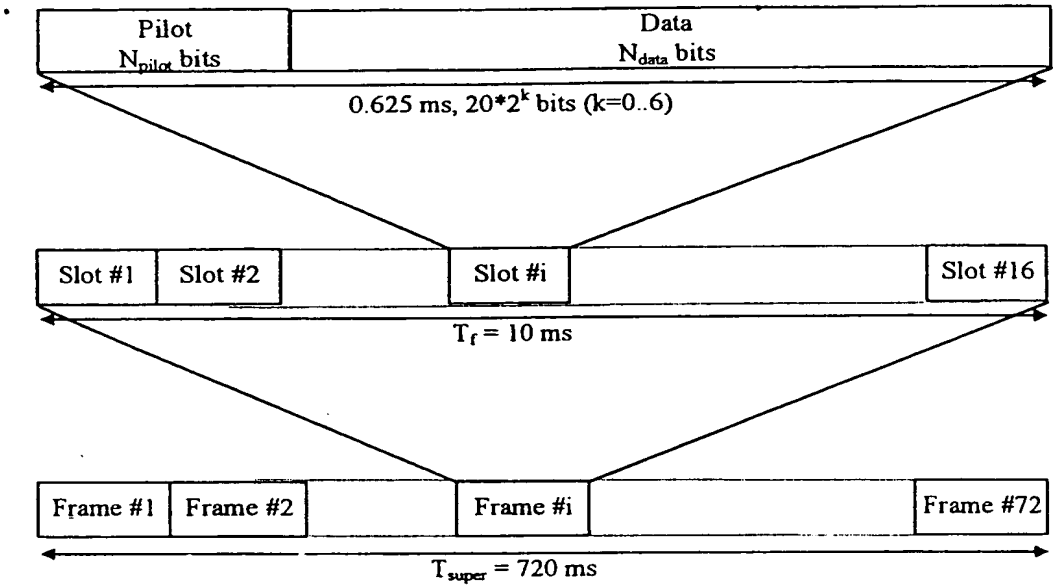
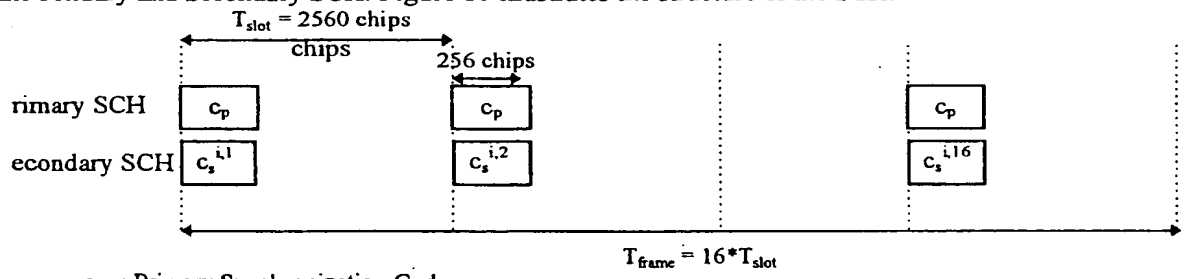


Figure 9. Frame structure for Secondary Common Control Physical Channel.

The FACH and PCH are mapped to separate Secondary CCPCHs. The main difference between a CCPCH and a downlink dedicated physical channel is that a CCPCH is not power controlled. The main difference between the Primary and Secondary CCPCH is that the Primary CCPCH has a fixed predefined rate while the Secondary CCPCH has a constant rate that may be different for different cells, depending on the capacity needed for FACH and PCH. Furthermore, a Primary CCPCH is continuously transmitted over the entire cell while a Secondary CCPCH is only transmitted when there is data available and may be transmitted in a narrow lobe in the same way as a dedicated physical channel (only valid for a Secondary CCPCH carrying the FACH).

2.3.3.2.3 Synchronisation Channel

The Synchronisation Channel (SCH) is a downlink signal used for cell search. The SCH consists of two sub channels, the Primary and Secondary SCH. Figure 10 illustrates the structure of the SCH:



c_p : Primary Synchronization Code
$c_s^{i,k}$: One of 17 possible Secondary Synchronization Codes
$(c_s^{i,1}, c_s^{i,2}, ..., c_s^{i,16})$ encode cell specific long scrambling code group i

Figure 10. Structure of Synchronisation Channel (SCH).

The Primary SCH consists of an *unmodulated* orthogonal Gold code of length 256 chips, the Primary Synchronisation Code, transmitted once every slot. The Primary Synchronisation Code is the same for every base station in the system and is transmitted time-aligned with the BCCH slot boundary as illustrated in Figure 10.

The Secondary SCH consists of repeatedly transmitting a length 16 sequence of *unmodulated* Orthogonal Gold codes of length 256 chips, the Secondary Synchronisation Codes, transmitted in parallel with the Primary Synchronisation channel. Each Secondary Synchronisation code is chosen from a set of 17 different Orthogonal Gold codes of length

256. This sequence on the Secondary SCH indicates which of the 32 different code groups (see Section 4.3.2.2) the base station downlink scrambling code belongs. 32 sequences are used to encode the 32 different code groups each containing 16 scrambling codes. The 32 sequences are constructed such that their cyclic-shifts are unique, i.e., a non-zero cyclic shift less than 16 of any of the 32 sequences is not equivalent to some cyclic shift of any other of the 32 sequences. Also, a non-zero cyclic shift less than 16 of any of the sequences is not equivalent to itself with any other cyclic shift less than 16. This property is used to uniquely determine both the long code group and the frame timing in the second step of acquisition (see Section 6.3.1). The following sequences are used to encode the 32 different code groups each containing 16 scrambling codes (note that c_i indicates the i'th Secondary Short code of the 17 Orthogonal Gold codes).

$(c_1\ c_1\ c_2\ c_{11}\ c_6\ c_3\ c_{15}\ c_7\ c_8\ c_8\ c_7\ c_{15}\ c_3\ c_6\ c_{11}\ c_2)$
$(c_1\ c_2\ c_9\ c_3\ c_{10}\ c_{11}\ c_{13}\ c_{13}\ c_{11}\ c_{10}\ c_3\ c_9\ c_2\ c_1\ c_{16}\ c_{16})$
$(c_1\ c_3\ c_{16}\ c_{12}\ c_{14}\ c_2\ c_{11}\ c_2\ c_{14}\ c_{12}\ c_{16}\ c_3\ c_1\ c_{13}\ c_4\ c_{13})$
$(c_1\ c_4\ c_6\ c_4\ c_1\ c_{10}\ c_9\ c_8\ c_{17}\ c_{14}\ c_{12}\ c_{14}\ c_{17}\ c_8\ c_9\ c_{10})$
$(c_1\ c_5\ c_{13}\ c_{13}\ c_5\ c_1\ c_7\ c_{14}\ c_3\ c_{16}\ c_8\ c_8\ c_{16}\ c_3\ c_{14}\ c_7)$
$(c_1\ c_6\ c_3\ c_5\ c_9\ c_9\ c_5\ c_3\ c_6\ c_1\ c_4\ c_2\ c_{15}\ c_{15}\ c_2\ c_4)$
$(c_1\ c_7\ c_{10}\ c_{14}\ c_{13}\ c_{17}\ c_3\ c_9\ c_9\ c_3\ c_{17}\ c_{13}\ c_{14}\ c_{10}\ c_7\ c_1)$
$(c_1\ c_8\ c_{17}\ c_6\ c_{17}\ c_8\ c_1\ c_{15}\ c_{12}\ c_5\ c_{13}\ c_7\ c_{13}\ c_5\ c_{12}\ c_{15})$
$(c_1\ c_9\ c_7\ c_{15}\ c_4\ c_{16}\ c_{16}\ c_4\ c_{15}\ c_7\ c_9\ c_1\ c_{12}\ c_{17}\ c_{17}\ c_{12})$
$(c_1\ c_{10}\ c_{14}\ c_7\ c_8\ c_7\ c_{14}\ c_{10}\ c_1\ c_9\ c_5\ c_{12}\ c_{11}\ c_{12}\ c_5\ c_9)$
$(c_1\ c_{11}\ c_4\ c_{16}\ c_{12}\ c_{15}\ c_{12}\ c_{16}\ c_4\ c_{11}\ c_1\ c_6\ c_{10}\ c_7\ c_{10}\ c_6)$
$(c_1\ c_{12}\ c_{11}\ c_8\ c_{16}\ c_6\ c_{10}\ c_5\ c_7\ c_{13}\ c_{14}\ c_{17}\ c_9\ c_2\ c_{15}\ c_3)$
$(c_1\ c_{13}\ c_1\ c_{17}\ c_3\ c_{14}\ c_8\ c_{11}\ c_{10}\ c_{15}\ c_{10}\ c_{11}\ c_8\ c_{14}\ c_3\ c_{17})$
$(c_1\ c_{14}\ c_8\ c_9\ c_7\ c_5\ c_6\ c_{17}\ c_{13}\ c_{17}\ c_6\ c_5\ c_7\ c_9\ c_8\ c_{14})$
$(c_1\ c_{15}\ c_{15}\ c_1\ c_{11}\ c_{13}\ c_4\ c_6\ c_{16}\ c_2\ c_2\ c_{16}\ c_6\ c_4\ c_{13}\ c_{11})$
$(c_1\ c_{16}\ c_5\ c_{10}\ c_{15}\ c_4\ c_2\ c_{12}\ c_2\ c_4\ c_{15}\ c_{10}\ c_5\ c_{16}\ c_1\ c_8)$
$(c_1\ c_{17}\ c_{12}\ c_2\ c_2\ c_{12}\ c_{17}\ c_1\ c_5\ c_6\ c_{11}\ c_4\ c_4\ c_{11}\ c_6\ c_5)$
$(c_2\ c_8\ c_{11}\ c_{15}\ c_{14}\ c_1\ c_4\ c_{10}\ c_{10}\ c_4\ c_1\ c_{14}\ c_{15}\ c_{11}\ c_8\ c_2)$
$(c_2\ c_9\ c_1\ c_7\ c_1\ c_9\ c_2\ c_{16}\ c_{13}\ c_6\ c_{14}\ c_8\ c_{14}\ c_6\ c_{13}\ c_{16})$
$(c_2\ c_{10}\ c_8\ c_{16}\ c_5\ c_{17}\ c_{17}\ c_5\ c_{16}\ c_8\ c_{10}\ c_2\ c_{13}\ c_1\ c_1\ c_{13})$
$(c_2\ c_{11}\ c_{15}\ c_8\ c_9\ c_8\ c_{15}\ c_{11}\ c_2\ c_{10}\ c_6\ c_{13}\ c_{12}\ c_{13}\ c_6\ c_{10})$
$(c_2\ c_{12}\ c_5\ c_{17}\ c_{13}\ c_{16}\ c_{13}\ c_{17}\ c_5\ c_{12}\ c_2\ c_7\ c_{11}\ c_8\ c_{11}\ c_7)$
$(c_2\ c_{13}\ c_{12}\ c_9\ c_{17}\ c_7\ c_{11}\ c_6\ c_8\ c_{14}\ c_{15}\ c_1\ c_{10}\ c_3\ c_{16}\ c_4)$
$(c_2\ c_{14}\ c_2\ c_1\ c_4\ c_{15}\ c_9\ c_{12}\ c_{11}\ c_{16}\ c_{11}\ c_{12}\ c_9\ c_{15}\ c_4\ c_1)$
$(c_2\ c_{15}\ c_9\ c_{10}\ c_8\ c_6\ c_7\ c_1\ c_{14}\ c_1\ c_7\ c_6\ c_8\ c_{10}\ c_9\ c_{15})$
$(c_2\ c_{16}\ c_{16}\ c_2\ c_{12}\ c_{14}\ c_5\ c_7\ c_{17}\ c_3\ c_3\ c_{17}\ c_7\ c_5\ c_{14}\ c_{12})$
$(c_2\ c_{17}\ c_6\ c_{11}\ c_{16}\ c_5\ c_3\ c_{13}\ c_3\ c_5\ c_{16}\ c_{11}\ c_6\ c_{17}\ c_2\ c_9)$
$(c_2\ c_1\ c_{13}\ c_3\ c_3\ c_{13}\ c_1\ c_2\ c_6\ c_7\ c_{12}\ c_5\ c_5\ c_{12}\ c_7\ c_6)$
$(c_2\ c_2\ c_3\ c_{12}\ c_7\ c_4\ c_{16}\ c_8\ c_9\ c_9\ c_8\ c_{16}\ c_4\ c_7\ c_{12}\ c_3)$
$(c_2\ c_3\ c_{10}\ c_4\ c_{11}\ c_{12}\ c_{14}\ c_{14}\ c_{12}\ c_{11}\ c_4\ c_{10}\ c_3\ c_2\ c_{17}\ c_{17})$
$(c_2\ c_4\ c_{17}\ c_{13}\ c_{15}\ c_3\ c_{12}\ c_3\ c_{15}\ c_{13}\ c_{17}\ c_4\ c_2\ c_{14}\ c_5\ c_{14})$
$(c_2\ c_5\ c_7\ c_5\ c_2\ c_{11}\ c_{10}\ c_9\ c_1\ c_{15}\ c_{13}\ c_{15}\ c_1\ c_9\ c_{10}\ c_{11})$

The use of the SCH for cell search is described in detail in Section 6.3.

2.4 Mapping of Transport Channels to Physical Channels

Figure 11 summarises the mapping of transport channels to physical channels.

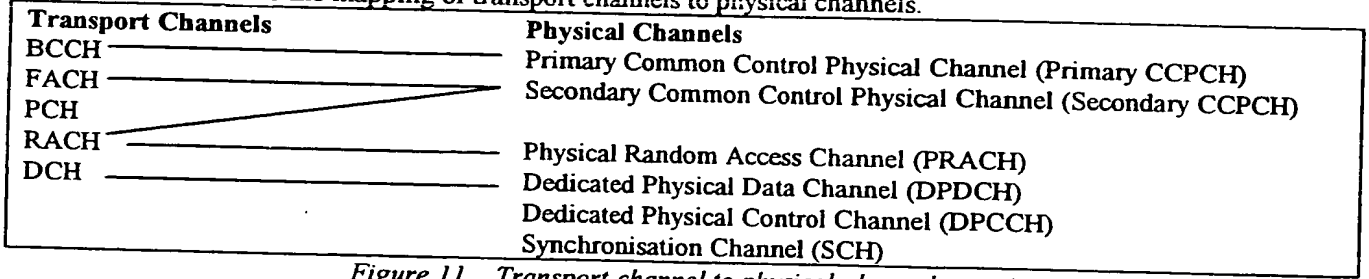


Figure 11. Transport-channel to physical-channel mapping.

The DCHs are coded and multiplexed as described in Section 3, and the resulting data stream is mapped sequentially (first-in-first-mapped) directly to the physical channel(s). The mapping of BCCH and FACH is equally straightforward, where the data stream after coding and interleaving is mapped sequentially to the Primary and

4.3.2.3 Synchronisation codes

The Primary and Secondary code words, C_p and $\{C_1,\ldots,C_{17}\}$ respectively, consist of pair wise mutually orthogonal Gold codes of length 256. The Primary SCH is furthermore chosen to have good aperiodic auto correlation properties. The code sequences are constructed with the help of two binary *m*-sequences of length 255, *x*, and *y*, respectively. The *x* sequence is constructed using the polynomial $1+X^2+X^3+X^4+X^8$. The *y* sequence is constructed using the polynomial $1+X^3+X^5+X^6+X^8$.

Before we define the Primary and Secondary code words, we define the set of orthogonal Gold codes.

Let $n_7 \ldots n_0$ be the binary representation of the scrambling code number *n* (decimal) with n_0 being the least significant bit. The *x* sequence depends on the chosen code number *n* and is denoted x_n in the sequel. Furthermore, let $x_n(i)$ and $y(i)$ denote the *i*:th symbol of the sequence x_n and *y*, respectively

The *m*-sequences x_n and *y* are constructed as:

Initial conditions:

$x_n(0)=n_0, x_n(1)=n_1, \ldots =x_n(6)=n_6, x_n(7)=n_7$

$y(0)=y(1)=\ldots =y(6)=y(7)=1$

Recursive definition of subsequent symbols:

$x_n(i+8) =x_n(i+4) + x_n(i+3) + x_n(i+2) + x_n(i)$ *modulo 2*, $i=0,\ldots, 246$,

$y(i+8) = y(i+6)+ y(i+5)+ y(i+3)+y(i)$ *modulo 2*, $i=0,\ldots, 246$.

The definition of the *n*:th SCH code word follows (the left most index correspond to the chip transmitted first in each slot):

$C_{SCH,n} = < 0, x_n(0)+y(0), x_n(1)+y(1), \ldots, x_n(254)+y(254) >$,

All sums of symbols are taken modulo 2.

Note that the code words always start with a constant '0'. symbol.

Before modulation and transmission these binary code words are converted to real valued sequences by the transformation '0' -> '+1', '1' -> '-1'.

The Primary and Secondary code words are defined in terms of $C_{SCH,n}$ and the definition of C_p and $\{C_1,\ldots,C_{17}\}$ now follows as:

$C_p = C_{SCH,0}$

and

$C_i = C_{SCH,i}$, i=1,...,17

4.3.3 Modulation

4.3.3.1 Modulating chip rate

The modulating chip rate is 4.096 Mcps. This basic chip rate can be extended to 8.192 or 16.384 Mcps.

4.3.3.2 Pulse shaping

The pulse-shaping filters are root raised cosine (RRC) with roll-off α=0.22 in the frequency domain.

4.3.3.3 Modulation

QPSK modulation is used.

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5 Radio transmission and reception (FDD)

<Editor's note: Input needed on many of the topics in this section.>

5.1 General

The information presented in this section is based on a chip rate of 4.096 Mcps. Appropriate adjustments should be made for higher chip rate options.

5.2 Frequency bands and channel arrangement

5.2.1 Proposed frequency bands for operation

UTRA/FDD is designed to operate in the following paired band:

1920 – 1980 MHz	2110 – 2170 MHz
Mobile station transmit	Mobile station receive
Base station receive	Base station transmit

Table 3. Proposed frequency band for UTRA/FDD

Deployment in other frequency bands is not precluded.

5.5.2 Carrier spacing

The nominal channel spacing is 5 MHz, but this can be adjusted to optimise performance in particular deployment scenarios. The channel raster is 200 kHz, which means that the carrier frequency must be a multiple of 200 kHz.

5.2.3 TX – RX frequency separation

The minimum transmit to receive separation is 130 MHz when operating in the paired band defined in Table 3.

5.2.4 Variable duplex distance

UTRA/FDD should support a variable duplex distance, i.e. $D_{duplexer} = F_{down} - F_{up}$ is not necessary a constant but is, in general, allowed to vary within certain limits. The specific limits for the duplex distance applicable for different frequency bands and terminal classes are yet to be determined.

5.3 Service classes

5.3.1 Terminal service classes

A number of different service classes will be used to define the data rate and code allocation for a UTRA/FDD terminal. Possible types of service class profiles are 144 kbps, 384 kbps and 2048 kbps.

5.4 Transmitter characteristics

The output power is given in terms of power level at the antenna connector of the equipment. For equipment with integral antenna only, a reference antenna with a gain of 0 dBi is assumed.

5.4.1 Mobile station output power

The mobile station output power profile would be used to define a range of terminal output powers for use in different system scenarios. The power class would be based on the mobile station's peak power for example 30 dBm. For mobile station using directive antennas for transmission, a class dependent limit will be placed on the maximum EIRP (Equivalent Isotropic Radiated Power).

5.4.2 Base station output power

The base station output power profile would be used to cater for different system scenarios. The power class would be based on the peak power specified for the base stations.

5.4.3 Output power dynamics

The transmitter uses fast closed-loop Carrier/Interference based power control and slow quality-based power control on both the uplink and downlink.

	Uplink (UL)	Downlink (DL)
Power control steps	Variable 0.25-1.5 dB	Variable 0.25-1.5 dB
Minimum transmit power	-50 dBm	[ ] dBm
Power control cycles per second	1.6 kHz	1.6 kHz
Power control dynamic	80 dB	30 dB

Table 4. Output power dynamics for UL and DL

5.4.4 Output RF spectrum emissions

5.4.4.1 Out of band emissions

The assumed spectrum mask has been derived from simulations on a real wide band amplifier as shown in Figure 27 below. These emission levels will be dependent on the power class and code allocation of the mobile and base station.

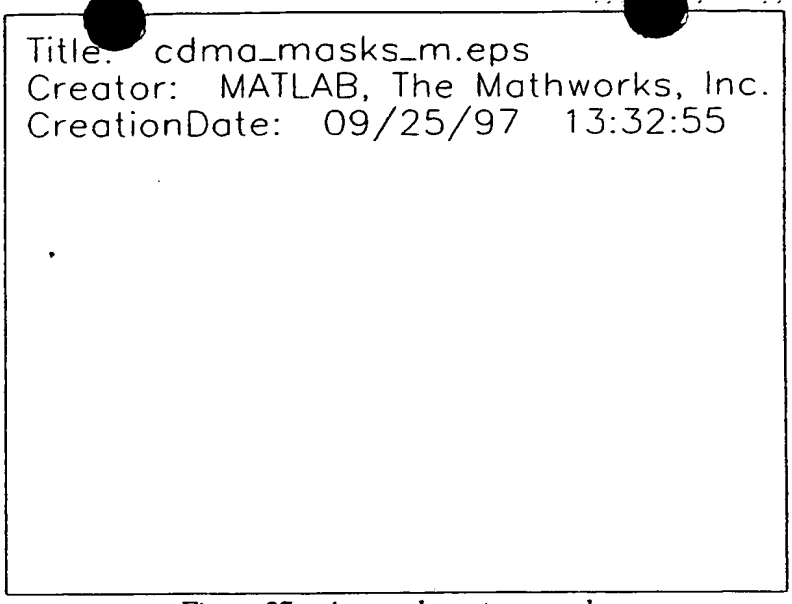

Figure 27. Assumed spectrum masks.

5.4.4.2 Spurious emissions

The limits for spurious emissions at frequencies greater than ± 250% of the necessary bandwidth would be based on the applicable tables from ITU-R Recommendation SM.329. Further guidance would be taken from the ERC recommendation that is currently under progress.

5.4.5 Adjacent channel protection (ACP)

Adjacent channel protection (ACP) is the ratio of the transmitted power and the power measured after a receiver filter in the adjacent channel.

The ACP envisaged for 5 MHz channel spacing is in the order of 35 dB to 40 dB. The possibility is being considered of dynamically relaxing the ACP requirements for mobile stations under conditions when this would not lead to significant interference (with respect to other systems or UMTS operators). This would be carried out under network control, primarily to facilitate reduction in MS power consumption.

5.4.6 Occupied bandwidth

The channel bandwidth is less than 5 MHz based on a chip rate of 4.096 Mcps.

5.4.7 Frequency stability

The frequency stability for the mobile and base station is indicated in Table 5.

Mobile station	Base station
3 PPM (unlocked), 0.1 PPM (locked)	0.05 PPM

Table 5. Mobile and base station frequency stability.

5.5 Receiver characteristics

A Rake receiver or any other suitable receiver structure using coherent reception in both channel impulse response estimation, and code tracking procedures is assumed.

5.5.1 Diversity characteristics

Three forms of diversity are available in UTRA / FDD:

Time diversity	Channel coding and interleaving in both up link and down link.
Multi-path diversity	Rake receiver or other suitable receiver structure with maximum combining. Additional processing elements can increase the delay-spread performance due to increased capture of signal energy.

Space diversity	Antenna diversity with maximum ratio combing in base station and optionally in the mobile stations. Possibility for downlink transmit diversity in the base station.

Table 6. Diversity characteristics for UTRA/FDD.

5.5.2 Reference sensitivity level

The reference sensitivity for the following services; 8 kbps, 144 kbps, 384 kbps and 2048 kbps are specified in the link budget template for a number of test environments and multi-path channel classes.

5.5.3 BER noise floor level

The BER noise floor level for voice services is significantly less than 10^{-3} BER. The BER noise floor level for data services is significantly less than 10^{-6} BER.

5.5.4 Maximum tolerable delay spread

To maintain the voice and data service quality requirements the UTRA/FDD concept allows for a time dispersion spread suitable for the various propagation models specified in UMTS 30.03.

5.5.5 Maximum tolerable Doppler spread

The maximum tolerable Doppler spread is 1000 Hz, which at a 2 GHz carrier frequency corresponds to a maximum velocity of about 500 km/hr. Parameters determining system performance are not necessarily optimised for this value of Doppler spread.

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6 Physical layer procedures (FDD)

6.1 General

6.2 Power control

6.2.1 Uplink power control

6.2.1.1 Closed loop power control

The uplink closed loop power control adjusts the mobile station transmit power in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target.

The base station should estimate the received uplink DPCCH power after RAKE combining of the connection to be power controlled. Simultaneously, the base station should estimate the total uplink received interference in the current frequency band and generate a SIR estimate SIR_{est}. The base station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,UL} \rightarrow$ TPC command = "down"

$SIR_{est} < SIR_{target,UL} \rightarrow$ TPC command = "up"

Upon the reception of a TPC command, the mobile station should adjust the transmit power of both the uplink DPCCH and the uplink DPDCH in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells, in the region 0.25 – 1.5 dB.

In case of receiver diversity (e.g., space diversity) or softer handover at the base station, the TPC command should be generated after diversity combining.

In case of soft handover, the following procedure is considered:

- in the base stations a quality measurement is performed on the received signals; in case the quality measurement indicates a value below a given threshold, an increase command is sent to the mobile, otherwise a decrease command is transmitted; all the base stations in the active set send power control commands to the mobile;
- the mobile compares the commands received from different base stations and increases its power only if all the commands indicate an increase value (this means that all the receivers are below the threshold); in case one command indicates a decrease step (that is, at least one receiver is operating in good conditions), the mobile reduces its power; in case more than one decrease commands are received by the mobile, the mobile station should adjust the power with the largest step in the "down" direction ordered by the TPC commands received from each base station in the active set.
- the quality threshold for the base stations in the active set should be adjusted by the outer loop power control (to be implemented in the network node were soft handover combining is performed).

6.2.1.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the uplink DPDCH and uplink DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.

6.2.1.3 Open-loop power control

Open-loop power control is used to adjust the transmit power of the physical Random-Access channel. Before the transmission of a Random-Access burst, the mobile station should measure the received power of the downlink Primary CCPCH over a sufficiently long time to remove effects of the non-reciprocal multi-path fading. From the power estimate and knowledge of the Primary CCPCH transmit power (broadcast on the BCCH) the downlink path-loss including shadow fading can be found. From this path loss estimate and knowledge of the uplink interference level and the required received SIR, the transmit power of the physical Random-Access channel can be determined. The uplink interference level as well as the required received SIR are broadcast on the BCCH.

6.2.2 Downlink power control

6.2.2.1 Closed loop power control

The downlink closed loop power control adjusts the base station transmit power in order to keep the received downlink SIR at a given SIR target.

The mobile station should estimate the received downlink DPCH power after RAKE combining of the connection to be power controlled. Simultaneously, the mobile station should estimate the total downlink received interference in the current frequency band. The mobile station then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,DL} \rightarrow$ TPC command = "down"

$SIR_{est} < SIR_{target,DL} \rightarrow$ TPC command = "up"

Upon the reception of a TPC command, the base station should adjust the transmit power in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells, in the range 0.25 – 1.5 dB. In case of receiver diversity (e.g., space diversity) at the mobile station, the TPC command should be generated after diversity combining.

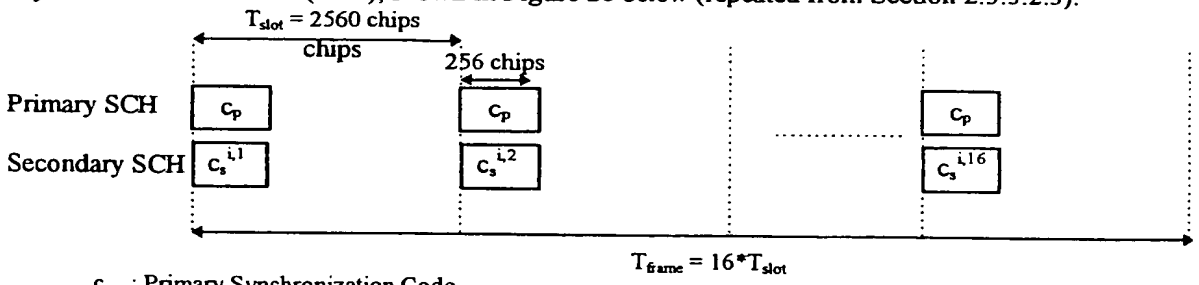
6.2.2.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the downlink DPDCH and DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.

6.3 Cell search

6.3.1 Initial cell search

During the initial cell search, the mobile station searches for the base station to which it has the lowest path loss. It then determines the downlink scrambling code and frame synchronisation of that base station. The initial cell search uses the synchronisation channel (SCH), shown in Figure 28 below (repeated from Section 2.3.3.2.3).



c_p : Primary Synchronization Code

$c_s^{i,k}$: One of 17 possible Secondary Synchronization Codes

$(c_s^{i,1}, c_s^{i,2}, ..., c_s^{i,16})$ encode cell specific long scrambling code group i

Figure 28. Structure of synchronisation channel (SCH).

This initial cell search is carried out in three steps:

Step 1: Slot synchronisation

During the first step of the initial cell search procedure the mobile station uses the primary SCH to acquire slot synchronisation to the strongest base station. This is done with a single matched filter (or any similar device) matched to the primary synchronisation code c_p which is common to all base stations. The output of the matched filter will have peaks for each ray of each base station within range of the mobile station, see Figure 29. Detecting the position of the strongest peak gives the timing of the strongest base station modulo the slot length. For better reliability, the matched-filter output should be non-coherently accumulated over a number of slots.

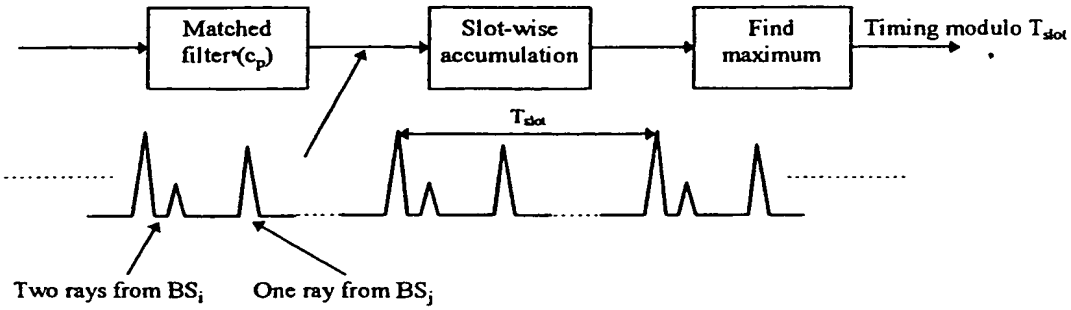


Figure 29. Matched-filter search for primary synchronisation code to slot synchronisation (timing modulo the slot length).

Step 2: Frame synchronisation and code-group identification

During the second step of the initial cell search procedure, the mobile station uses the secondary SCH to find frame synchronisation and identify the code group of the base station found in the first step. This is done by correlating the received signal at the positions of the Secondary Synchronisation Code with all possible (17) Secondary Synchronisation Codes. Note that the position of the Secondary Synchronisation Code is known after the first step. The outputs of all the 17 correlators for 16 consecutive secondary SCH locations are used to form the decision variables. The decision variables are obtained by *non-coherently* summing the correlator outputs corresponding to each 16 length sequence out of the 32 possible sequences and its 16 cyclic shifts giving a total of 512 decision variables. Note that the cyclic shifts of the sequences are unique (see Section 2.3.3.2.2). Thus, by identifying the sequence/shift pair that gives the maximum correlation value, the code group as well as the frame synchronisation is determined.

Step 3: Scrambling-code identification

During the third and last step of the initial cell-search procedure, the mobile station determines the exact scrambling code used by the found base station. The scrambling code is identified through symbol-by-symbol correlation over the Primary CCPCH with all scrambling codes within the code group identified in the second step. Note that, from step 2, the frame boundary and consequently the start of the scrambling code is known. Correlation must be carried out symbol-wise, due to the unknown data of the primary CCPCH. Also, in order to reduce the probability of wrong/false acquisition, due to combat background noise/interference, averaging the correlator outputs over a sequence of symbols (diversity) might be required before using the outputs to determine the exact scrambling code.

After the scrambling code has been identified, the Primary CCPCH can be detected, super-frame synchronisation can be acquired and the system- and cell specific BCCH information can be read.

6.3.2 Idle mode cell search

When in idle mode, the mobile station continuously searches for new base stations on the current and other carrier frequencies. The cell search is done in basically the same way as the initial cell search. The main difference compared to the initial cell search is that an idle mobile station has received a priority list from the network. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search (step 3). Also the complexity in the second step may be reduced if the priority list only includes scrambling codes belonging to a subset of the total set of code groups. The priority list is continuously updated to reflect the changing neighbourhood of a moving mobile station.

6.3.3 Active mode cell search

When in active mode, the mobile station continuously searches for new base stations on the current carrier frequency. This cell search is carried out in basically the same way as the idle mode cell search. The mobile station may also search for new base stations on other carrier frequencies using the slotted mode, see Section 6.5.2.1.1.

6.4 Random access

The procedure of a random access request is: